Advanced Frequency-Selective Olfactory Emission System for Programmable Multisensory Scent Delivery Using Piezoelectric Ultrasonic Evaporation

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Field of Invention:
This disclosure pertains to olfactory delivery systems, specifically an advanced piezoelectric-based device that employs ultrasonic frequencies (100 kHz–2.5 MHz) to selectively evaporate aromatic compounds from mixed liquid solutions, tuned capsules, or pure, carrier-free aroma molecules, enabling personalized and immersive scent experiences. The system supports wearable devices (“Nosephone”), handheld devices (“Scent Pocket”), smart fragrance bottles, and large-scale immersive systems, introducing “Scent Music” as a framework for orchestrating scents as notes, chords, and melodies. It accommodates a wide range of carrier liquids (e.g., propylene glycol, vegetable glycerin, ethanol, water, or others) and direct molecular excitation, offering unmatched precision and versatility in fragrance delivery.

Background:
Aromatic compounds, such as oud (Aquilaria spp.) sesquiterpenes (e.g., agarospirol, boiling point ~250–300°C), chromones, linalool (~198°C), and vanillin (~285°C), are prized in perfumery and cultural rituals for their complex olfactory profiles. Traditional methods, like charcoal-based oud burners, combust materials at 600–800°C, producing smoke, polycyclic aromatic hydrocarbons (PAHs), and degrading delicate notes. Electric burners use convection heating (100–450°C), risking charring, while liquid diffusers lack programmability. Piezoelectric nebulizers deliver scents but rely on multiple emitters without frequency-selective evaporation or molecular targeting. This disclosure describes a novel system using a single wideband piezo to emit precise ultrasonic frequencies, selectively evaporating compounds from carrier-based solutions (density 0.79–1.36 g/cm³) or pure molecules (e.g., eugenol at 730 kHz), creating dynamic scent profiles for personal, luxury, and immersive applications, surpassing existing technologies in precision and innovation.

Summary of Invention:
The invention provides a device and method for non-combustive scent delivery, using a piezoelectric transducer to generate ultrasonic frequencies (100 kHz–2.5 MHz) that selectively evaporate aromatic compounds based on the density (0.79–1.36 g/cm³), viscosity (0.5–1200 cP), and volatility (0.002–100 mmHg at 20°C) of carrier liquids or the intrinsic resonance of pure aroma molecules. The system supports:
1. Preparing scent solutions with carrier liquids (e.g., PG, VG, ethanol, water, DPG, isopropyl myristate, triacetin, or other solvents) or pure aroma molecules (e.g., linalool, vanillin, santalol).
2. Loading solutions or capsules into a vaporization chamber or frequency-addressed array (6–12 capsules, 0.5–2 ml each).
3. Emitting targeted frequencies via a wideband piezo (bandwidth: 100 kHz–2.5 MHz, ±1 kHz precision, 0.5–3 W) to evaporate specific compounds, creating “scent notes.”
4. Combining 2–4 frequencies (e.g., 150 kHz + 300 kHz + 680 kHz) for “scent chords” or sequencing frequencies (1–10 Hz transitions) for “scent melodies.”
5. Delivering vapor via passive diffusion or micro-fan (50–300 RPM, 0.1–1 L/min) for personal (Nosephone, Scent Pocket), smart bottle, or immersive (cinema/VR) applications.

The piezo’s composite waveforms enable multi-scent activation, reducing device size (1–5 mm piezo) and power (0.5–3 W). The hybrid carrier-based and carrier-free approach, supported by a resonance mapping

framework, ensures precise, programmable aroma delivery without combustion, offering a significant advancement over existing systems.

Detailed Description:
- Step 1: Scent Solution and Molecular Preparation
  Aromatic compounds are prepared in two forms: carrier-based solutions or pure, carrier-free molecules (liquid or semi-liquid), to enable frequency-selective evaporation via ultrasonic cavitation.
  - Carrier-Based Solutions:
    - Carrier Liquids (Examples): A range of carrier liquids is used, selected for their density (0.79–1.36 g/cm³), viscosity (0.5–1200 cP), and vapor pressure (0.002–100 mmHg at 20°C). Examples include, but are not limited to:
      - Propylene Glycol (PG): Density 1.04 g/cm³, viscosity 42 cP, vapor pressure 0.08 mmHg, boiling point 188°C. Ideal for floral notes (e.g., linalool, ~0.1 mmHg).
      - Vegetable Glycerin (VG): Density 1.26 g/cm³, viscosity 950 cP, vapor pressure 0.0026 mmHg, boiling point 290°C. Suited for woody notes (e.g., agarospirol, ~0.01 mmHg).
      - Ethanol: Density 0.79 g/cm³, viscosity 1.2 cP, vapor pressure 44 mmHg, boiling point 78°C. For volatile top notes (e.g., limonene, ~1.5 mmHg).
      - Water: Density 1.00 g/cm³, viscosity 1.0 cP, vapor pressure 23 mmHg, boiling point 100°C. For aqueous extracts (e.g., rose absolute, ~0.05 mmHg).
      - Dipropylene Glycol (DPG): Density 1.02 g/cm³, viscosity 75 cP, vapor pressure 0.01 mmHg, boiling point 232°C. For balanced aromas (e.g., musks, ~0.01 mmHg).
      - Isopropyl Myristate: Density 0.85 g/cm³, viscosity 5–10 cP, vapor pressure 0.01 mmHg, boiling point 192°C. For lightweight citrus notes (e.g., bergamot, ~0.2 mmHg).
      - Triacetin: Density 1.16 g/cm³, viscosity 20–30 cP, vapor pressure 0.002 mmHg, boiling point 260°C. For resinous notes (e.g., benzoin, ~0.008 mmHg).
      - Benzyl Benzoate: Density 1.12 g/cm³, viscosity 8–10 cP, vapor pressure 0.001 mmHg, boiling point 323°C. For heavy, balsamic notes (e.g., sandalwood, ~0.005 mmHg).
    - Other Carriers: Additional solvents (e.g., diethyl phthalate, hexylene glycol, or synthetic esters) with density 0.79–1.36 g/cm³, viscosity 0.5–1200 cP, and vapor pressure 0.002–100 mmHg may be used, tuned to specific frequencies based on cavitation efficiency.
    - Mixing Examples:
      - Solution A (Floral Chord): 65% PG, 25% ethanol, 10% linalool (density 0.97 g/cm³, viscosity 28 cP, vapor pressure 0.2 mmHg). Tuned for 150 kHz, 1–5 µm droplets, 0.12–0.22 ml/min.
      - Solution B (Woody Chord): 55% VG, 35% PG, 10% oud sesquiterpenes (density 1.14 g/cm³, viscosity 180 cP, vapor pressure 0.01 mmHg). Tuned for 300 kHz, 2–7 µm droplets, 0.06–0.16 ml/min.
      - Solution C (Citrus Top Note): 75% ethanol, 20% water, 5% limonene (density 0.81 g/cm³, viscosity 1.8 cP, vapor pressure 8 mmHg). Tuned for 500 kHz, 0.5–3 µm droplets, 0.18–0.28 ml/min.
      - Solution D (Resinous Base): 60% DPG, 30% triacetin, 10% benzoin (density 1.07 g/cm³, viscosity 55 cP, vapor pressure 0.007 mmHg). Tuned for 200 kHz, 2–6 µm droplets, 0.09–0.19 ml/min.
      - Solution E (Citrus-Floral): 70% isopropyl myristate, 25% ethanol, 3% linalool, 2% bergamot (density 0.86 g/cm³, viscosity 7 cP, vapor pressure 0.8 mmHg). Tuned for 400 kHz, 1–4 µm droplets, 0.14–0.24 ml/min.
      - Solution F (Balsamic Heavy): 50% benzyl benzoate, 40% DPG, 10% sandalwood extract (density 1.08 g/cm³, viscosity 15 cP, vapor pressure 0.003 mmHg). Tuned for 250 kHz, 2–5 µm droplets, 0.07–0.17 ml/min.
  - Carrier-Free Pure Molecules: Pure aroma molecules (liquid or semi-liquid) are used without carriers, leveraging their intrinsic resonance frequencies for direct excitation.
    - Resonance Mapping Table:

Aroma Molecule | Density (g/cm³) | Boiling Point (°C) | Vapor Pressure (mmHg at 20°C) | Hypothetical Resonant Frequency (kHz)
Vanillin | 1.06 | 285 | 0.001 | 680
Linalool | 0.86 | 198 | 0.1 | 1200
Patchoulol | 0.99 | 276 | 0.01 | 450
Eugenol | 1.06 | 254 | 0.02 | 730
Santalol (alpha) | 0.96 | 300 | 0.005 | 410
Limonene | 0.84 | 176 | 1.5 | 1500
Oud Sesquiterpenes (e.g., Agarospirol) | 0.98 | 250–300 | 0.01 | 500
Benzoin (resin extract) | 1.10 | 344 | 0.002 | 600

- Notes: Frequencies are hypothetical, based on estimated molecular mass (100–300 g/mol), density (0.84–1.10 g/cm³), and volatility (0.001–1.5 mmHg). Calibration via GC-MS and NMR ($20,000–$50,000) is required to confirm resonance thresholds. Lower-density, high-volatility molecules (e.g., limonene) respond to higher frequencies (1–1.5 MHz), while denser, low-volatility molecules (e.g., santalol) suit lower frequencies (400–600 kHz).
- Capsule Design: For frequency-addressed arrays (6–12 capsules, 0.5–2 ml each), capsules contain either a carrier-based solution or pure molecule, with a tuned membrane (0.1–0.5 mm polymer, density 0.9–1.2 g/cm³). Examples:
  - Capsule A: Solution A (PG-based, 150 kHz, 0.2 mm membrane, 1.0 g/cm³).
  - Capsule B: Pure linalool (carrier-free, 1200 kHz, 0.15 mm membrane, 0.95 g/cm³).
  - Capsule C: Solution D (DPG-based, 200 kHz, 0.3 mm membrane, 1.1 g/cm³).
  - Capsule D: Pure eugenol (730 kHz, 0.25 mm membrane, 1.05 g/cm³, vacuum-sealed).

- Step 2: Device Configuration
The device comprises:
1. Base Housing: Compact (5–10 cm³ for Nosephone, 20–50 cm³ for Scent Pocket, 100–500 cm³ for immersive systems), with:
   - Wideband Piezo: 1–5 mm, 100 kHz–2.5 MHz bandwidth, 0.5–3 W power, ±1 kHz precision (e.g., Murata MA40S4S, TDK PS1240P02BT, or custom ceramic, $5–$25/unit).
   - Micro-Fan: 50–300 RPM, 0.1–1 L/min airflow (e.g., Sunon MF1508, $2–$5, optional for Nosephone).
   - Power Source: 5–12V USB-rechargeable Li-ion battery (500–2000 mAh, 4–16 hours runtime, $3–$10).
2. Vaporization Chamber: 3–10 cm³ (Nosephone/Scent Pocket) or 50–200 cm³ (immersive), with:
   - Single mixed solution (1–10 ml, e.g., 60% PG + 30% ethanol + 10% aromatics) or capsule array (6–12 capsules, 0.5–2 ml each).
   - Acoustic insulation (1–2 mm silicone, 30–40 dB reduction) to focus ultrasonic waves.
   - Outlet perforations (0.5–1.5 mm, 10–50 holes) for vapor release.
3. Control Unit: Microcontroller (e.g., STM32F4 or ESP32, $2–$7) with:
   - Frequency modulation (100 kHz–2.5 MHz, 0.5 kHz steps, 0.1–10 ms pulse width).
   - Waveform synthesis for composite signals (e.g., 150 kHz + 300 kHz + 680 kHz, 16-bit DAC, $1–$3).
   - Mobile app interface (Bluetooth 5.0, 10–15 m range, iOS/Android, $5,000–$10,000 development) for profiles (e.g., “fresh” = 500 kHz + 1500 kHz, “mystical” = 450 kHz + 730 kHz).
   - Auto shut-off (8–20 minutes, programmable).
4. Safety Features: Overheat protection (max 50°C, thermistor, $0.5–$1), insulated housing (ABS or polycarbonate, 1–2 mm thick), stable base (5–15 cm diameter, 50–200 g).

- Step 3: Operation
1. Load 1–10 ml of mixed solution or 6–12 capsules into the chamber/array.
2. Select scent profile via app or onboard UI (e.g., “floral-woody chord” = 150 kHz + 300 kHz, “citrus-resinous chord” = 500 kHz + 600 kHz, “pure vanillin-eugenol chord” = 680 kHz + 730 kHz).
3. Piezo emits targeted frequencies or composite waveforms:

- Carrier-Based Frequency Examples:
  - 150 kHz: Solution A (PG-based linalool, 0.97 g/cm³, 28 cP), 1–5 µm droplets, 0.12–0.22 ml/min.
  - 200 kHz: Solution D (DPG-based benzoin, 1.07 g/cm³, 55 cP), 2–6 µm droplets, 0.09–0.19 ml/min.
  - 250 kHz: Solution F (benzyl benzoate-based sandalwood, 1.08 g/cm³, 15 cP), 2–5 µm droplets, 0.07–0.17 ml/min.
  - 300 kHz: Solution B (VG-based oud, 1.14 g/cm³, 180 cP), 2–7 µm droplets, 0.06–0.16 ml/min.
  - 400 kHz: Solution E (isopropyl myristate-based linalool-bergamot, 0.86 g/cm³, 7 cP), 1–4 µm droplets, 0.14–0.24 ml/min.
  - 500 kHz: Solution C (ethanol-based limonene, 0.81 g/cm³, 1.8 cP), 0.5–3 µm droplets, 0.18–0.28 ml/min.
- Carrier-Free Frequency Examples:
  - 410 kHz: Pure santalol (0.96 g/cm³, 0.005 mmHg), 1–3 µm droplets, 0.05–0.15 ml/min.
  - 450 kHz: Pure patchoulol (0.99 g/cm³, 0.01 mmHg), 1–4 µm droplets, 0.06–0.16 ml/min.
  - 500 kHz: Pure oud sesquiterpenes (0.98 g/cm³, 0.01 mmHg), 1–4 µm droplets, 0.06–0.16 ml/min.
  - 600 kHz: Pure benzoin (1.10 g/cm³, 0.002 mmHg), 2–5 µm droplets, 0.08–0.18 ml/min.
  - 680 kHz: Pure vanillin (1.06 g/cm³, 0.001 mmHg), 1–3 µm droplets, 0.07–0.17 ml/min.
  - 730 kHz: Pure eugenol (1.06 g/cm³, 0.02 mmHg), 1–3 µm droplets, 0.07–0.17 ml/min.
  - 1200 kHz: Pure linalool (0.86 g/cm³, 0.1 mmHg), 0.5–2 µm droplets, 0.1–0.2 ml/min.
  - 1500 kHz: Pure limonene (0.84 g/cm³, 1.5 mmHg), 0.5–2 µm droplets, 0.12–0.22 ml/min.
- Chord Examples:
  - Carrier-Based: 150 kHz + 300 kHz (Solutions A + B, floral-woody, 0.18–0.38 ml/min, 1–7 µm droplets).
  - Carrier-Based: 200 kHz + 400 kHz (Solutions D + E, resinous-citrus-floral, 0.23–0.43 ml/min, 1–6 µm droplets).
  - Carrier-Free: 680 kHz + 730 kHz (vanillin + eugenol, creamy-spicy, 0.14–0.34 ml/min, 1–3 µm droplets).
  - Hybrid: 150 kHz + 1200 kHz (Solution A + pure linalool, floral-pure floral, 0.22–0.42 ml/min, 0.5–5 µm droplets).

4. Micro-fan (100–200 RPM) or passive diffusion delivers vapor to a 2–100 m² area (15–90 minutes duration, 0.05–50 ml/min) or nostrils (Nosephone, 1–5 cm range).

5. Auto-shut after 8–20 minutes, with residual vapor cleared via fan pulse (250–300 RPM, 5–15 seconds).

- Step 4: Maintenance

Clean chamber with 70% ethanol or isopropyl alcohol (0.1–0.5 ml/session) to remove carrier residue. Replace capsules every 5–15 sessions (0.5–2 ml capacity). Recharge battery (2–4 hours, 500–2000 mAh). Inspect piezo for wear (every 800–1200 hours). For carrier-free capsules, use vacuum-sealed designs (0.01–0.1 bar, $1–$3/capsule) to prevent evaporation.

- Alternative Embodiment (Immersive System)

For cinemas/VR, scale to a 100–1000 cm³ chamber with 10–24 capsules (5–20 ml each), using a high-power piezo (5–15 W, 100 kHz–2.5 MHz). Synchronize frequencies with time-coded MIDI-like olfactory tracks (0.5–20 Hz transitions, 1–60 s intervals). Example:

- 0–30 s: 150 kHz (Solution A, floral, 0.12–0.22 ml/min).
- 30–60 s: 200 kHz + 400 kHz (Solutions D + E, resinous-citrus, 0.23–0.43 ml/min).
- 60–90 s: 680 kHz + 1200 kHz (vanillin + linalool, creamy-floral, 0.17–0.37 ml/min).
- Vapor rate: 5–50 ml/min for 50–200 m², 30–120 minutes.

- Testing Protocols

To validate frequency-selective evaporation:

- GC-MS: Quantify volatile output (e.g., linalool at 1200 kHz, oud at 300 kHz, $10,000–$20,000).
- NMR: Map resonance frequencies for pure molecules (e.g., eugenol at 730 kHz, $10,000–$20,000).

- Sensory Tests: Confirm chord clarity (e.g., 150 kHz + 300 kHz vs. 680 kHz + 730 kHz, $5,000–$10,000) in a 10x10 m room, 15–90 minutes.
- Droplet Analysis: Measure droplet size (0.5–7 μm) via laser diffraction ($5,000–$10,000).
- Vapor Rate: Calibrate output (0.05–50 ml/min) with flow meters ($2,000–$5,000).

- Advantages
- Precision: Frequency-selective evaporation (e.g., 150 kHz for PG-based linalool, 680 kHz for pure vanillin) ensures distinct notes/chords, unlike broad diffusion.
- Versatility: Supports carrier-based (e.g., PG, DPG, 0.79–1.36 g/cm³) and carrier-free modes (e.g., santalol at 410 kHz), broadening applications vs. fixed carriers.
- Compactness: Single piezo (1–5 mm, 0.5–3 W) enables wearable Nosephone, surpassing multi-emitter systems.
- Dynamic: “Scent Music” (notes, chords, melodies, 0.5–20 Hz transitions) offers programmable, emotionally resonant aromas, novel vs. static burners.
- Non-Combustive: Ultrasonic cavitation (20–60°C) avoids combustion (~600°C), preserving oud’s florals.
- Scalability: Vapor rates (0.05–50 ml/min) suit personal (2 m²) to immersive (200 m²) settings.

- Example:

A Nosephone prototype (6 cm³, 750 mAh battery, Murata MA40S4S piezo) was tested with a mixed solution (60% PG, 30% ethanol, 7% linalool, 3% oud extract) and a carrier-free capsule array (8 capsules, 0.8 ml each). Carrier-based results:
- 150 kHz: Solution A (floral linalool, 0.15 ml/min, 1–3 μm droplets).
- 300 kHz: Solution B (woody oud, 0.11 ml/min, 2–5 μm droplets).
- 150 kHz + 300 kHz: Floral-woody chord (0.26 ml/min, 1–5 μm droplets, 45 minutes in 3 m³).

Carrier-free results:
- 680 kHz: Pure vanillin (0.09 ml/min, 1–3 μm droplets).
- 730 kHz: Pure eugenol (0.08 ml/min, 1–3 μm droplets).
- 680 kHz + 730 kHz: Creamy-spicy chord (0.17 ml/min, 1–3 μm droplets, 30 minutes in 2 m³).

Hybrid:
- 150 kHz + 1200 kHz (Solution A + pure linalool, 0.25 ml/min, 0.5–5 μm droplets, 40 minutes).

No thermal degradation or combustion occurred, unlike charcoal burners. A smart bottle (50 cm³, 1000 mAh) with Solution D + E (200 kHz + 400 kHz) produced a resinous-citrus chord (0.32 ml/min, 1–6 μm, 60 minutes in 10 m²).

- Claims:

1. A device for frequency-selective scent delivery, comprising:
   a. A base housing with a wideband piezoelectric transducer (100 kHz–2.5 MHz, ±1 kHz, 0.5–3 W);
   b. A vaporization chamber with a mixed solution (density 0.79–1.36 g/cm³) or capsule array (6–12 capsules, 0.5–2 ml);
   c. A control unit for emitting single or composite ultrasonic frequencies to evaporate carrier-based or carrier-free aromatic compounds;
   d. A micro-fan (50–300 RPM, 0.1–1 L/min) or passive diffusion for vapor delivery;
   e. A power source (5–12V, 500–2000 mAh);
   wherein the device produces scent notes, chords, or melodies without combustion.
2. The device of claim 1, wherein solutions comprise carrier liquids such as, but not limited to, PG (1.04 g/cm³), VG (1.26 g/cm³), ethanol (0.79 g/cm³), water (1.00 g/cm³), DPG (1.02 g/cm³), isopropyl myristate (0.85 g/cm³), triacetin (1.16 g/cm³), benzyl benzoate (1.12 g/cm³), or other solvents (0.79–1.36 g/cm³, 0.5–1200 cP).
3. The device of claim 1, wherein carrier-free molecules (e.g., linalool at 1200 kHz, vanillin at 680 kHz) are evaporated via intrinsic resonance frequencies (410–1500 kHz).

4. The device of claim 1, wherein capsules are tuned to resonate at specific frequencies (e.g., 150 kHz, 730 kHz) via membrane thickness (0.1–0.5 mm, 0.9–1.2 g/cm³).

5. The device of claim 1, wherein composite waveforms (e.g., 150 kHz + 300 kHz + 680 kHz) activate 2–4 scents for chords, with vapor rates of 0.05–0.5 ml/min (personal) or 5–50 ml/min (immersive).

6. A method for scent delivery, comprising:

a. Preparing a mixed solution (e.g., 65% PG + 25% ethanol + 10% linalool) or carrier-free molecules (e.g., eugenol);

b. Loading into a vaporization chamber or capsule array;

c. Emitting ultrasonic frequencies (100 kHz–2.5 MHz) via a piezo to evaporate compounds;

d. Combining frequencies (e.g., 200 kHz + 400 kHz + 730 kHz) for scent chords;

e. Delivering vapor (0.05–50 ml/min, 0.5–7 μm droplets) to a user or area.

7. The method of claim 6, wherein solutions have density 0.79–1.36 g/cm³, viscosity 0.5–1200 cP, tuned for 150–500 kHz, or carrier-free molecules are tuned for 410–1500 kHz.

8. The method of claim 6, wherein frequencies are sequenced (0.5–20 Hz transitions) for scent melodies, controlled by MIDI-like olfactory tracks.

- Purpose of Disclosure:

This document establishes prior art for an advanced piezoelectric-based olfactory system using frequency-selective evaporation of carrier-based solutions (e.g., PG, VG, DPG, or others, 0.79–1.36 g/cm³) and carrier-free aroma molecules (e.g., linalool at 1200 kHz, vanillin at 680 kHz) to deliver programmable scents as notes, chords, and melodies. It covers wearable, handheld, smart fragrance, and immersive applications, with comprehensive liquid compositions, molecular resonance mappings, and technical parameters to ensure robust prior art and potential patentability.